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IMPROVED PROCESS AND METHOD FOR DEGASSING AND SEPARATION OF INCLUSIONS IN A LIQUID METAL BATH BY INJECTION OF GAS BUBBLES

Field of the Invention

Technical domain

The invention relates to a process and a device for improving the degassing treatment and separation of inclusions in a liquid metal bath, and particularly aluminium, magnesium or their alloys, by injection and dispersion of a gas in the said liquid metal.

Sate of the art

It is known that before semi-finished metallurgical products such as aluminium, magnesium and their alloys can be obtained by casting, the unfinished liquid metal has to be treated to eliminate dissolved gases (particularly hydrogen), dissolved impurities (particularly alkalis) and solid or liquid inclusions that would reduce the quality of the cast parts.

This treatment is usually done by insufflation of an appropriate gas, for example an inert gas insoluble in a liquid metal such as Ar that can contain a few percent of a reactive chlorine type gas.

If this treatment is to be efficient, the bubble diameter must be as small as possible to give a large contact area between the gas and the metal.

For example, patent application FR 2 727 432 in the name of the applicant discloses the insufflation of gas through a porous material inert to the liquid metal, usually based on graphite or alumina.

But this approach cannot be used to control the flow and size of the emitted gas bubbles. When the pores are too large, firstly the bubbles are too large,

they are not efficient, the gas being insufficiently dispersed in the liquid metal, and the result is unwanted surface movements, and furthermore it is essential that the gas flow through the pores is not stopped to prevent the liquid metal from penetrating into them, particularly during rest periods between two pours. On the other hand, when the pores are too small, the bubbles spread and remain large; it is also difficult to introduce a high gas flow inside the liquid metal.

Thus, the device in the application mentioned above tends to get around this difficulty of controlling the bubble diameter and obtaining small diameter bubbles by means of a particular layout of gas emitting devices.

Similarly, patent US 4714494 describes a process for reducing the diameter of bubbles emitted through a porous medium. This process consists of treating the liquid metal in a long chute, the bottom of which is made of a porous material through which the gas is inlet and in which the said liquid metal circulates at speed of at least 0.1 cm/sec, and preferably at least 2.5 cm/sec. Although the bubble diameter can be reduced with this process, it is still large. Furthermore, it is not easy to control the liquid metal at high speed, there may be safety risks and a high speed may not be compatible with a good quality of liquid metal, considering the swirling that may take place within its mass.

Thus, there are several known processes that make use of porous diffusers to obtain bubbles of the order of 30 to 50 mm diameter at best, even if the pores are very fine, for example less than 1 mm, or liquid metal

circulation speeds of the order of magnitude of those described in US patent 4714494.

SUMMARY OF THE INVENTION

American patent US 4 290 590 describes a gas bubble injection device comprising a plate of inert material and a series of protuberances provided with orifices in their upper part and supplied by a gas source in their lower part. The orifice of the protuberances should be as small as possible, which has the disadvantage of necessitating a large number of protuberances to obtain a sufficient gas flow.

The applicant has continued making efforts to control and reduce the diameter of bubbles emitted by a static gas insufflation device and thus make it more efficient.

Description of the invention

The invention is a device for the injection of gas bubbles into a liquid metal contained in a treatment volume, the said device comprising at least one static injection part (also called emitter) made of a substantially inert material, the said static part comprising a plurality of orifices, the said device being characterised in that the material and/or layout of the orifices are such that the ratio of the diameter of the contact area between each emitted bubble and the said material at the exit from the orifice, to the outlet diameter of the orifice, or the spreading ratio, is less than 5, preferably less than 3, or more preferably less than 1.5.

The treatment volume or container is usually a tank with one or several compartments, a liquid metal circulation chute, a furnace, etc.

The orifice diameter is equal to not more than the diameter of the bubble to be obtained, and the smaller the bubble diameter to be obtained the smaller the required spreading ratio. The device according to the invention is particularly useful when it is required to obtain bubbles with a diameter not larger than 20 mm and advantageously not more than 10 mm, even when the liquid is calm or is circulating at low speed. The bubble diameter can be even smaller when the liquid metal is circulating at a higher speed.

The required spreading ratio may be obtained using a material that can be wetted by the liquid metal, in other words if the wetting angle is less than 90°, and/or by geometrically limiting the spreading area available around the orifice; the latter solution makes it possible to use diffusers made of a material that cannot be wetted by the liquid metal.

FIGURE 1 (a and b) illustrates the difference in behaviour between a wettable and non-wettable material within the context of the invention.

(1) shows the static emitter body, (2) shows the gas inlet orifice at which a bubble (9) is formed on the surface of the emitter, the said orifice (2) being supplied with gas through a small channel formed in the emitter.

When the material is wettable by the liquid metal (case in FIGURE 1a), the wetting angle (10) defined by the tangent to the bubble (9) at its contact point with the emitter and by the emitter is less than 90°. It can be seen that if the metal thoroughly wets the emitter material, the spreading of the bubble (9) is reduced and the diameter is limited. This mechanism, that occurs even if the surface surrounding the orifice

(2) forms an angle other than 90° with the inside surface of the orifice, is a means of allowing the gas to escape through protuberances made of a material that can be wetted by the metal, for example in the shape of drilled cones in which the orifice passes through the axis of symmetry, in other words the orifices may be located at the top of tapered protuberances. However, the use of a static emitter without a protuberance does have the advantage that it simplifies production of the device, and reduces the risks of geometry changes due to erosion and dirt accumulation on the device. The protuberances may possibly be formed from separate parts that are fixed together by mechanical means such as fasteners, which makes it easy to change them if damage occurs.

When the material cannot be wetted by the liquid metal (case in FIGURE 1b), the wetting angle (10) is greater than 90°. It can be seen that the bubble can spread because the metal cannot easily wet the emitter; in this case it is important to mechanically or geometrically limit the spreading area of the said bubble, as will be seen later, to ensure that its diameter is small.

The said contact area means the maximum contact surface A between each emitted bubble and the said material at the exit from the orifice. When a bubble develops, the contact area usually increases very quickly towards its maximum value. The maximum contact area can be measured using any means for displaying the formation of gas bubbles such as X-rays.

In the case of aluminium or magnesium and their liquid alloys, the wettable material of the diffuser may be chosen among some refractory metals that are

substantially inert to the said liquid metals, such as Mo, W, V, Ti, Cr, Fe, steels, etc., or their alloys, or among ceramics such as TiB_2, nitrides (AlN, BN), carbides (Al_4C_3, TiC_{1-x}), etc. In this respect, it can be noted that normally the graphite or aluminium is not wettable by these liquid metals. ZrO2 and SiC are also materials that cannot be wetted by aluminium and its alloys. The wetting behaviour of the material also depends on the roughness and the oxidation condition of its surface. The material is preferably wetting since in this case it is easier to obtain a low spreading ratio.

In order to physically limit the spreading ratio, the diffuser may comprise several small protuberances, the area at the top of these protuberances corresponding to the said contact area or spreading area of the bubble and comprises at least one gas emission orifice. With this type of diffuser, it can be seen that it is possible to use materials that are not wettable by the liquid metal; in this case, it is preferable to use a single orifice on the top of the protuberance. The height of these protuberances is preferably equal to at least said diameter, and their shape is preferably in the form of a straight or inclined cylindrical or tapered projection. The protuberances (32) or part of these protuberances may be removable, in other words they may form inserts so that they can be replaced if they are worn or damaged. The removable protuberances (or projections) may be fixed to the body of the static part (21) by fasteners or by any means that enable easy replacement of the protuberances.

The diffuser may be in the form of a single part or an assembly of elementary parts, usually thin parts in which small conduits have been drilled. The top end of these conduits forms the injection orifice located on the surface of the said diffuser in contact with the liquid metal, and their lower end forms the orifice into which the supply gas flow to be injected into the liquid metal is inlet. The distance between two adjacent injection orifices is typically slightly greater than the distance corresponding to the diameter of the spreading surface and is such that the bubbles do not touch each other while they are being formed. The conduits may correspond to a system of pores or may communicate through a network of feed conduits formed in the mass.

It is important that the gas pressure at the outlet orifice, at the interface between the metal and the surface of the emitter, is approximately constant regardless of the gas flow, particularly during formation and detachment of the bubble, in order to have better control over the bubble diameter. In this respect, it is advantageous to design the device such that the bubble volume located between the gas outlet orifice and the closest gas supply adjustment device (valve, flow meter, etc.) is as small as possible, and/or to use an appropriate mass flow meter, and/or to introduce a local pressure head loss just on the upstream side of the outlet orifice, for example using a porous material.

In order to further reduce the bubble diameter, it could be advantageous to inject a shearing energy into the liquid metal, for example by means of ultrasounds

or a rotary stirrer in order to facilitate separation of the bubbles.

The injection device according to the invention is advantageously used for the treatment of volumes of aluminium, magnesium, or their liquid alloys. For example, it may be installed in the bottom of liquid metal treatment tanks or compartments of these tanks, or in the bottom of circulation chutes for the said liquid metal.

The size of the bubbles (11, 31) may be measured by a method consisting of irradiating the liquid metal bath (3, 23) in which the bubbles are emitted by means of X-rays, displaying said bubbles after retrieving the image with a camera, and measuring them after calibration of the acquisition system and determining the spreading ratio.

The invention also relates to any process for the treatment of a liquid metal using gas bubbles with a diameter of not more than 20 mm, or preferably not more than 10 mm generated by a static diffuser, the products obtained by this process and the corresponding device. Tests carried out with this device according to the invention have shown that it is possible to achieve degassing efficiencies of up to 50% with bubbles with a diameter of the order of 5 mm, compared with previous efficiencies of less than 5% with bubbles with a diameter of the order of 40 mm. The invention also relates to any process for the treatment of liquid metals by the injection of gas using the static injection device according to this invention. For the embodiment of the treatment process, the material and/or the layout of the orifices in the static part (1, 21) may be chosen as a function of the nature of

the liquid metal, and possibly as a function of the gas composition and/or the temperature of the liquid metal.

The process may include measurement of the size of the bubbles under treatment, for example using X-rays, sound or ultrasound probes.

The drawings and the examples given below illustrate the invention.

Brief description of the drawings

FIGURE 2 shows a partial sectional view of an example diffuser used to obtain the spreading ratio according to the invention and FIGURE 3 shows a view of another diffuser according to the invention under the same conditions.

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Description of the preferred embodiments

FIGURE 2 shows the static diffuser at (1) in the form of a piece of material that is wettable by the liquid metal, usually installed in the bottom of a liquid aluminium treatment volume (not shown) comprising several injection orifices (2) in contact with the liquid metal (3). A treatment gas feed orifice (5) emerges on the lower face (4) of the part (1), the treatment gas being transported to the injection orifice (2) through the buffer volume (8). The diffuser rests on supports not shown and several diffusers may be installed in the same treatment volume as described in application FR 2727432 mentioned above.

With a 0.2 cm thick part (1) made of Ti (wettable by aluminium) with 1.0 mm diameter orifices (2) at a spacing of 15 mm from each other, the bubble (9) being formed has a wetting angle (10) equal to about 70° and a spreading ratio of about 1. The diameter of the bubbles formed (11) was measured by an X-ray method consisting essentially of irradiating the liquid metal bath in which the gas bubbles are emitted, and displaying the said bubbles as light images on a dark

background after retrieving the image by a camera; the diameter of the bubbles is then measured after calibration of the acquisition system.

The diameter is 5 mm while the metal is calm without the addition of any external shearing energy.

FIGURE 3 shows details of another method of limiting the spreading ratio. The static diffuser (21) placed in the bottom of a liquid metal treatment volume (23) is in the form of a part comprising injection orifices (22) through which the treatment gas is diffused into the liquid metal (23). These orifices are located at the top of the protuberances (32), and the top diameter is used with the orifice diameter to calculate the said spreading ratio. The injection orifices (22) are connected to the feed orifice (25) located on the lower face (24) of the part (21) through the buffer volume (28) that is as small as possible. As before, the constant pressure feed device (26) is on the upstream side of the said lower face (24).

With a graphite part (not wettable by aluminium) with orifices (22) with a diameter of 2 mm located at the top of small 10 mm diameter cylinders, thus with a spreading ratio of 5 with a height of 10 mm above the surface of the rest of the diffuser and with a spacing of 40 mm from each other, it is possible to obtain bubbles (31) with a diameter of about 10 mm. It can be seen that the bubble being formed (29) does not project beyond the periphery of the individualised non-wettable cylindrical projection (32) on which it is formed.

The constant pressure of gas supply device (6, 26), for example comprising graphite felt introducing a pressure loss between the supply gas flow (7, 27) and the buffer volume (8, 28) that is as small as possible,

is located on the upstream side of the lower face (4, 24) and typically at the orifice (5, 25).

Tests carried out with the device according to the invention have showed that the choice of material and the layout of the orifices alone is sufficient to efficiently control the size of the bubbles, even if this choice can be made as a function of the nature of the metal to be treated and/or, in some cases, as a function of the gas composition and/or the temperature of the liquid metal.